



# **EFFECTS OF REINFORCEMENTS (FIBER GLASS, $\text{TiO}_2$ AND $\text{Y}_2\text{O}_3$ ) WITH DIFFERENT VOLUME FRACTION ON THE MECHANICAL PROPERTIES OF EPOXY COMPOSITE**

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## **ABSTRACT**

*In this work, the influence of reinforcements on the mechanical properties of epoxy composites was studied and compared. Reinforcements, like titanium oxide ( $\text{TiO}_2$ ), Yttrium oxide ( $\text{Y}_2\text{O}_3$ ), and fiber glass, were added with different volume fraction (2.5, 5, 10, 15 and 20) % of the epoxy resin. Different mechanical tests are achieved to evaluate mechanical properties of composite such as; tensile, compression, hardness and impact test. The results revealed that, maximum tensile and yield strength were obtained at (5%) volume fraction of  $\text{TiO}_2$ , which increase the tensile strength (34.7%) and yield strength (40.1%) as compare with other reinforcements", while in compression test, (10%) volume fraction of fiber glass increase compression strength (14.48%) and yield strength (15%) as compared with other reinforcements. Higher hardness number was found at  $\text{TiO}_2$  which increase about (48%) as compare with epoxy composite. Impact strength was observed to be decreased by increasing volume fraction ratio up to (10%) for all reinforcements.*

**Keyword head:** Epoxy composites, Reinforcements, Mechanical Properties of Composite.

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## 1. INTRODUCTION

Conventional metal like ceramics, alloys and polymeric material doesn't meet the requirements of Modern technology, which is necessary materials with distinctive combination of properties. Composite material was defined as a mixing of more than one material those results in preferable mechanical properties more than those of individual component [1]. Epoxy composites are used in a wide range of industrial applications, like construction, furniture and automobiles. Comparing with metal materials, Epoxy composites have several advantages such as low density, lower cost, high strengths-to-weight ratios and good mechanical properties [2]. Iskender Ozsoy et al., studied the influence of the nano and micro-filler ratios for the epoxy composite on the mechanical properties, its result that filler ratios increasing with the decreasing of micro-filled composites [3]. Moorthy M. Nair et al., compare and utilize mechanical properties of epoxy composites reinforced with coal ash, increasing in impact, tensile, flexural and hardness behavior was observed [4]. TD Jagannatha and G Harish developed hybrid composites with different reinforcements of glass fiber and carbon fiber from (15, 30, 45 and 60) % epoxy composite, using different mechanical tests such as: hardness, ductility, tensile strength and peak load, the results shown that reinforced composite gave higher result than other composites [5]. Subita Bhagat, investigate mechanical characteristics of an epoxy composite as a reinforcement of titanium dioxide, the study show that particles of titanium dioxide added to epoxy composite have spectacular effects on mechanical properties [6]. Zhiwei Luo, estimate mechanical properties of  $\beta$ - $\text{Si}_3\text{N}_4$ -reinforced with  $\text{SiO}_2$ - $\text{Al}_2\text{O}_3$ - $\text{Y}_2\text{O}_3$  ( $\text{La}_2\text{O}_3$ ) ceramic composites, the fracture toughness, flexural strength, Vickers hardness and Young's modulus are effectively enhanced comparison with unreinforced ceramic matrix. It was observed from the literature that there was an enhancement of mechanical properties in epoxy composite when adding reinforced composite [7]. Therefore, in this work, mechanical properties of epoxy composites reinforced with titanium oxide ( $\text{TiO}_2$ ), Yttrium oxide ( $\text{Y}_2\text{O}_3$ ), and fiber glass, were added with different volume fraction had been studied and evaluated.

## 2. EXPERIMENTAL WORK

### 2.1 Material Used

A commercial epoxy (NITOPRIME 25 BASE) was selected a matrix material. And (K-6) epoxy Resin hardener was used. Reinforcements, such as titanium oxide ( $\text{TiO}_2$ ), Yttrium oxide ( $\text{Y}_2\text{O}_3$ ), and fiber glass, were added with different volume fraction (2.5%, 5 %, 10%, 15% and 20%), with particle size ( $\geq 45$  micron meter).

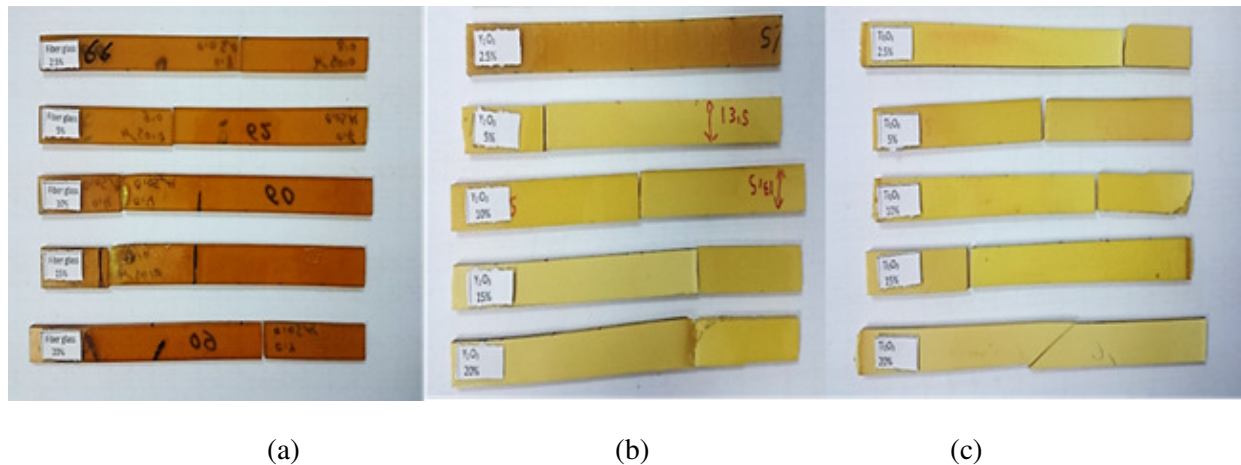
### 2.2. Preparation of Composite

Fabrication of the composite material was done using hand (lay-up) techniques. First of all, for epoxy without reinforcement composite (pure epoxy). Epoxy resin was poured inside a beaker with the hardener in the rate of (3/1) % and mixed well for 15 min. by hand stick. Then poured the mixture in a rectangular and circular mold for tensile and compression samples. Then it's kept at room temperature for 36 hr. thereafter put inside an oven for 15 hr. at 60 °C. Thus the pure epoxy sheet and rod were obtained.

While in case of epoxy reinforced composite, initially reinforcement was dried for 5 hr. at room temperature, then it's added to the epoxy resin and mixing for about 2 hr. Using mechanical stirrer. Hardener was then added slowly to the mixture to avoid gas bubble and mixed with hand stirring. Again the mixture of epoxy was poured in (circular and rectangular) moulds and leave for 36 hr. Later placed inside the oven for 15 hr. at 60 °C. A commercial epoxy (NITOPRIME 25 BASE) was selected a matrix material.

### 2.3. Testing of Mechanical Property

The epoxy composite samples with various reinforcements were ejected from the mold and prepared for suitable dimensions according to ASTM D638 in case of tensile samples Figure (1), and ASTM D695 for compression samples Figure (2), And the "Standard specimens for impact test were prepared according" to ASTM D6110-10 Figure (3). Mechanical properties of epoxy composite were estimated by tensile, compression, hardness and impact test. Tensile and compression test were done using universal testing machine, Zwick / Roell Z100, Figure (4), hardness test was achieved by (shore (D) Durometer Hardness tester), and Figure (5) (Tec Equipment Energy Absorbed At Fracture-TE15) was used to determine the impact energy. Three measurements were taken at different locations for each sample and the average of these values is calculated.



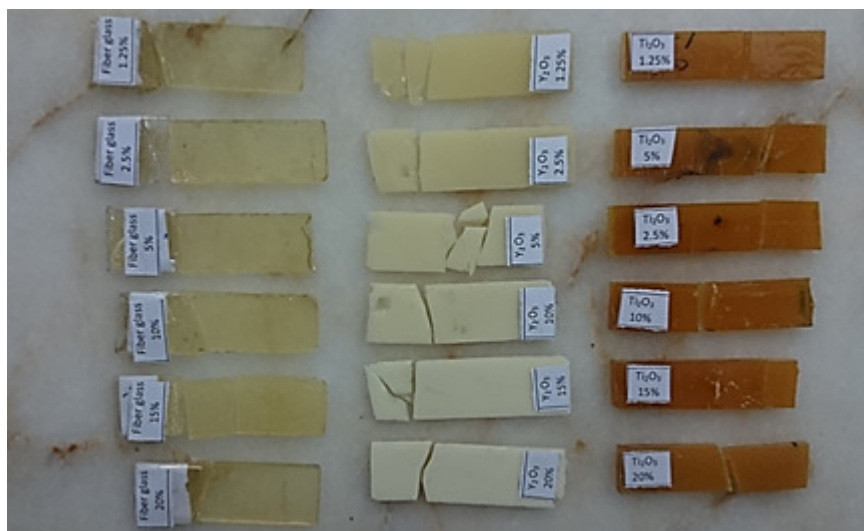
**Figure (1)** tensile test samples of epoxy composites with different reinforcements

(a) Fiber glass, (b)  $\text{TiO}_2$ , (c)  $\text{Y}_2\text{O}_3$  and different volume fraction.



**Figure 2** Compression test samples of epoxy composites with different reinforcements

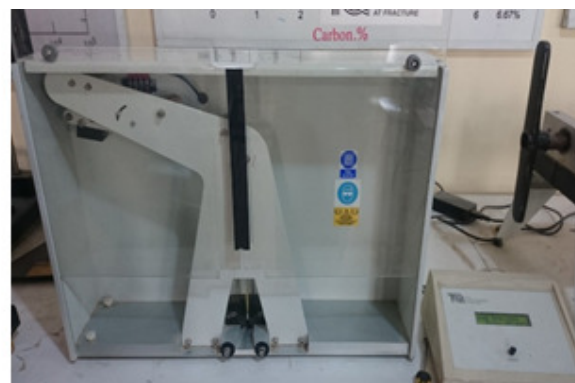
Fiber glass, (b)  $\text{TiO}_2$ , (c)  $\text{Y}_2\text{O}_3$  and different volume fraction.



**Figure 3** Impact test samples of epoxy composites with different reinforcements  
Fiber glass, (b)  $\text{TiO}_2$ , (c)  $\text{Y}_2\text{O}_3$  and different volume fraction.



**Figure 4** universal testing machine  
(Zwick / Roell Z100)



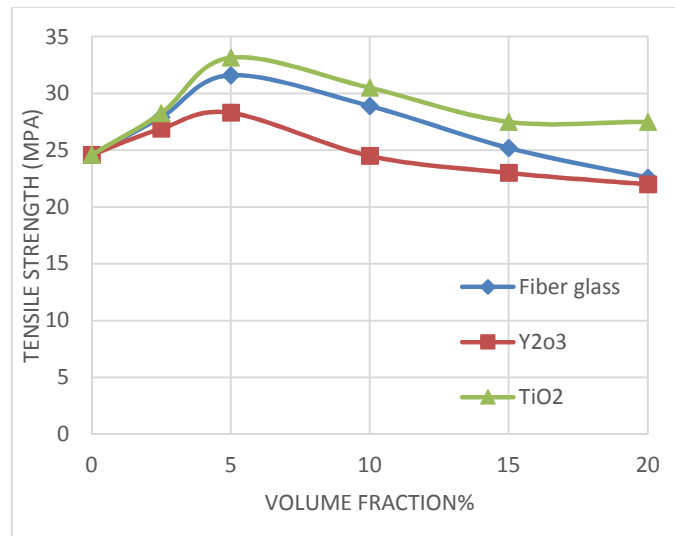
**Figure 5** Impact test equipment  
(TecQuipment Energy Absorbed At  
Fracture – TE15)

### 3. RESULTS AND DISCUSSION

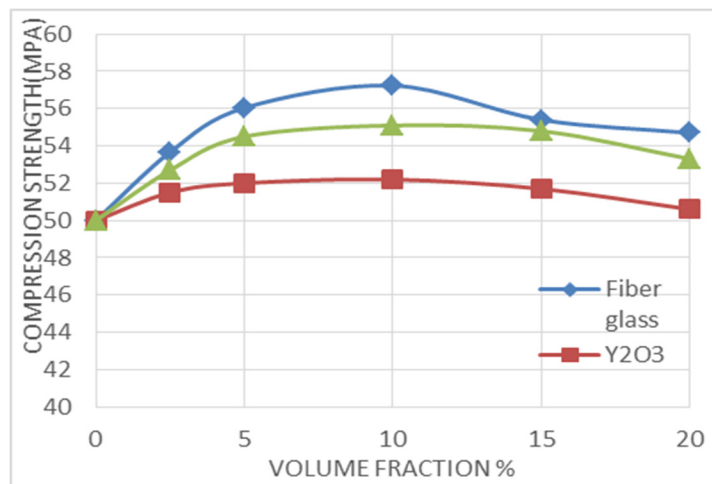
#### 3.1 Tensile and Compression Strength

Figure (6a) shows the relation between tensile strength versus volume fraction for different reinforcement of epoxy composite. The (5%) volume fraction of  $\text{TiO}_2$  shows (34.7%) increase in tensile strength as compare to (5%) volume fraction of fiber glass and  $\text{Y}_2\text{O}_3$  show (28.4%) and (15%) respectively. The highest increase of tensile strength belongs to  $\text{TiO}_2$  at (5%) because it's acting like elastic material during tension test. Figure (6b) presents the effect of volume fraction of different reinforcement with compressive strength, in this figure, fiber glass appears high compressive strength as compare with other reinforcements, whereas, (10%) increase in fiber glass shows (14.48%) increase in compressive strength while (10%) increase in  $\text{TiO}_2$  and  $\text{Y}_2\text{O}_3$  shows (10.2%) and (4.4%) increase in compressive strength respectively.

## Effects of Reinforcements (Fiber Glass, TiO<sub>2</sub> and Y<sub>2</sub>O<sub>3</sub>) with Different Volume Fraction on the Mechanical Properties of Epoxy Composite



(a)



(b)

**Figure 6** Effect of reinforcements composite on the strength of epoxy

(a) Tensile strength, (b) Compression strength

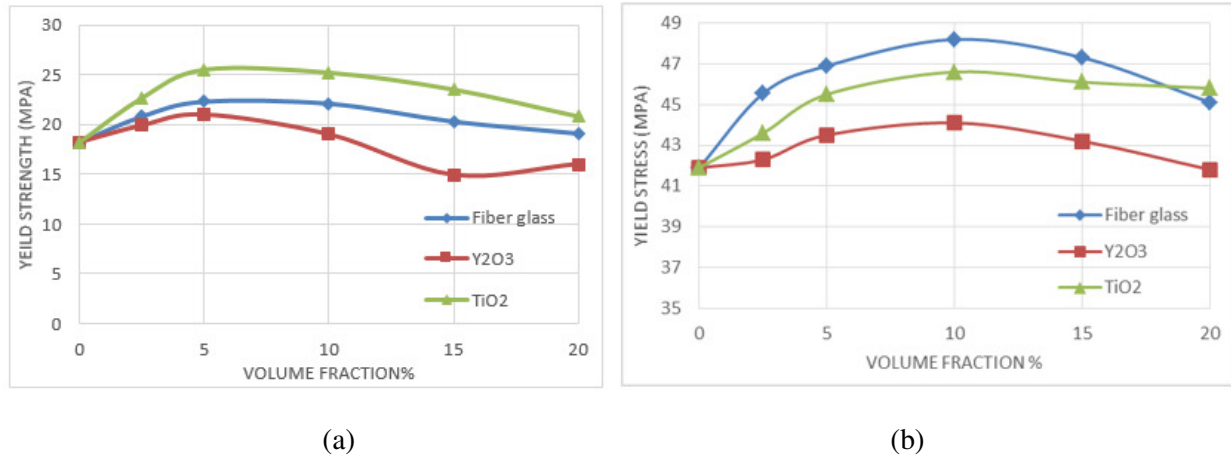
After which it start to drop, this may attributed to the agglomeration of fiber and voids formation as the fiber or particle increase in content, this leads to fiber -fiber or particle - particle contact as started by Manikandan and Manal with voids initiating cracks leading to fracture [8,9].

### 3.2 YIELD STRENGTH

Figure (7a) display the variation of yield strength and volume fraction for different reinforcement of composites in case of tensile test. The (5%) increase in TiO<sub>2</sub> volume fraction achieve (40.1%) increase in yield strength as compare with (5%) volume fraction of fiber glass and Y<sub>2</sub>O<sub>3</sub> which they achieved (22.5%) and (15.3%) increasing in yield strength respectively. While in case of compressive test, the (10%) volume fraction of fiber glass increase the yield strength about (15%) as compare with the same percentage of TiO<sub>2</sub> and Y<sub>2</sub>O<sub>3</sub> shows (11.1%) and (5.2%) respectively as shown in figure (7b).

It was clear from the results that the tensile strength and yield strength for the three reinforcement increase by increasing volume fraction up to (5 %), beyond this ratio increasing in volume fraction made no improvement to the tensile and yield strength because the reinforcement composite give the matrix a brittle behavior. Also for compressive and yield strength, (10%) volume fraction showed the highest increase in strength characteristics of the reinforced composite.

It was observed from the results that the compression strength of fiberglass epoxy composite higher than the tensile strength, due to in compression test the free volume in fiber composite lead to convert the composite from rigid to more flexible matrix.



**Figure 7** Effect of reinforcements composite on the yield strength of epoxy

(a) Tensile test, (b) Compression test

### 3.3 Hardness

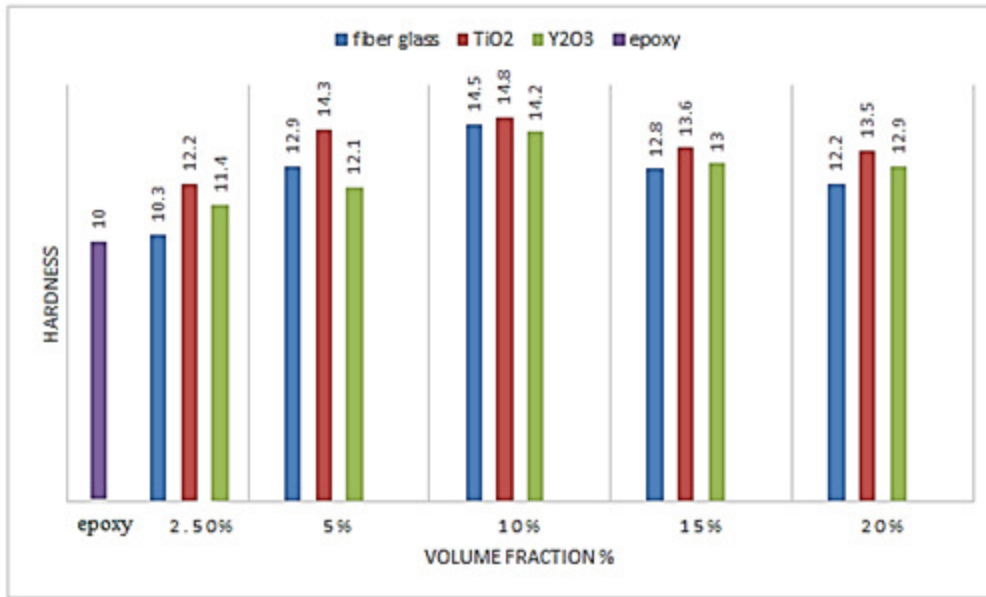
Hardness is known as resistance to surface penetration of the material. The results of hardness are summarized in Table (1) indicate that the hardness of the epoxy composites is affected by the concentration of volume fraction of reinforced materials.

**Table 1** Comparison of Hardness Number.

NO	Materials	Hardness
1	Epoxy	10.2
2	Fiber	14.5
3	TiO <sub>2</sub>	14.8
4	Y <sub>2</sub> O <sub>3</sub>	14.2

The results show that composite reinforced by (10%) volume fraction of TiO<sub>2</sub> exhibited increasing in hardness number about approximately (48%) from epoxy composite as comparing with other reinforced composites fiber glass and Y<sub>2</sub>O<sub>3</sub> which they achieved (45%) and (42%) as shown in Figure (8). The matrix exhibited good wettability on TiO<sub>2</sub> particles compared with other reinforcement material due to a good homogeneity and bonding strength between reinforcements and epoxy composites.

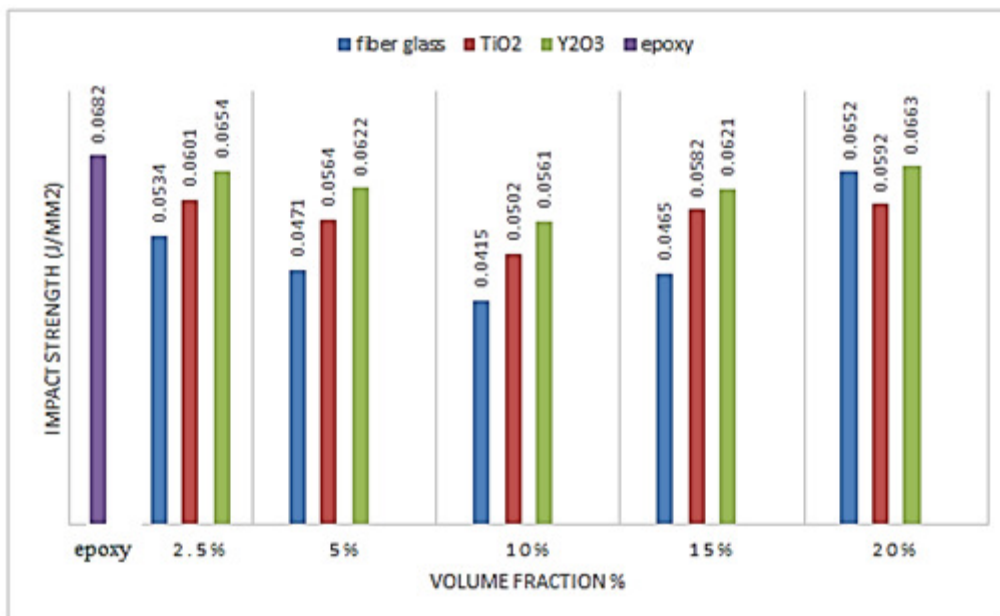




**Figure 8** Hardness number for different reinforced composite

### 3.4 Impact Strength

It's the ability of the material to resist the fracture under suddenly applied stress at high speed [10]. Figure (9) describe the decreasing in impact strength for different volume fractions of reinforced composites, the impact strength of composite was decrease with increasing in reinforcement's content due to the decrease in the availability of epoxy composite to bond all the reinforced particles in the matrix., poor impact strength of reinforced composites related to its high hardness value than that of non- reinforced one, however, impact property of composite material are related directly to the toughness of the materials. Hence, impact strength is a measure of toughness, so toughness and hardness are proportional inversely to each other.)While toughness increases, hardness decreases and vice versa.



**Figure 9** Represent impact strength of epoxy composites reinforced with different volume fractions

## 4. CONCLUSIONS

According to this study, the following conclusions were obtained:

1. It was observed that epoxy reinforced with (5%) volume fraction of Fiber glass exhibited a significant enhancement in tensile and yield strength as compared with other reinforced composite. While in compression test, (10%) volume fraction of  $\text{TiO}_2$  show high compression and yield strength as compared with other reinforcements.
2. Increasing volume fraction beyond (10%) in case of compression test, and (5%) in case of tensile test Leads to decrease in the strength properties of reinforced composites due to the brittle nature of epoxy composite when increasing in reinforcement ratios.
3. Results also indicate that composites reinforced with (10%) of  $\text{TiO}_2$  exhibit higher hardness number (14.8) when compare with other reinforced composites.
4. Increasing volume fractions will decrease impact strength of epoxy composite in different reinforcements.

In general, it was obvious from the results that reinforcement's content has a significant enhancement and effect on the mechanical properties of the epoxy composites, but this was only effective up to a certain percentage of volume fraction.

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